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DEVELOPMENT OF AN EMULATION-SIMULATION THERMAL CONTROL MODEL FOR SPACE STATION APPLICATION

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Submitted to

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ABSTRACT

The goal of this program is to develop an improved capability for comparing various techniques for thermal management in the "Space Station". The work involves three major tasks:

TASK I Develop a Technology Options Data Base.

TASK II Complete development of a Space Station Thermal Control Technology Assessment program.

TASK III Develop and evaluate emulation models.

INTRODUCTION

Current planning for the orbiting space station calls for a dual-keel configuration as shown in Figure 1. The thermal control system (TCS) for the space station is composed of a central TCS and internal thermal control systems for the modules, shown in Figure 2, as well as service facilities and attached payloads (hereinafter referred to as experimental truss and resource modules). The internal TCS may be attached to the central TCS through a thermal bus.

The central TCS is composed of a main transport system which collects waste thermal energy from each of the modules and transports it through coolant lines to the main rejection system. The main rejection system, in turn, is composed of steerable, constructable radiator elements attached to the transverse booms of the space station structure.

The waste heat loads in the modules arise from electrical and electronic equipment as well as metabolic loads in the manned modules. These equipment and metabolic loads may be collected by the central TCS or they may be transported to small radiators mounted on the body of individual modules.

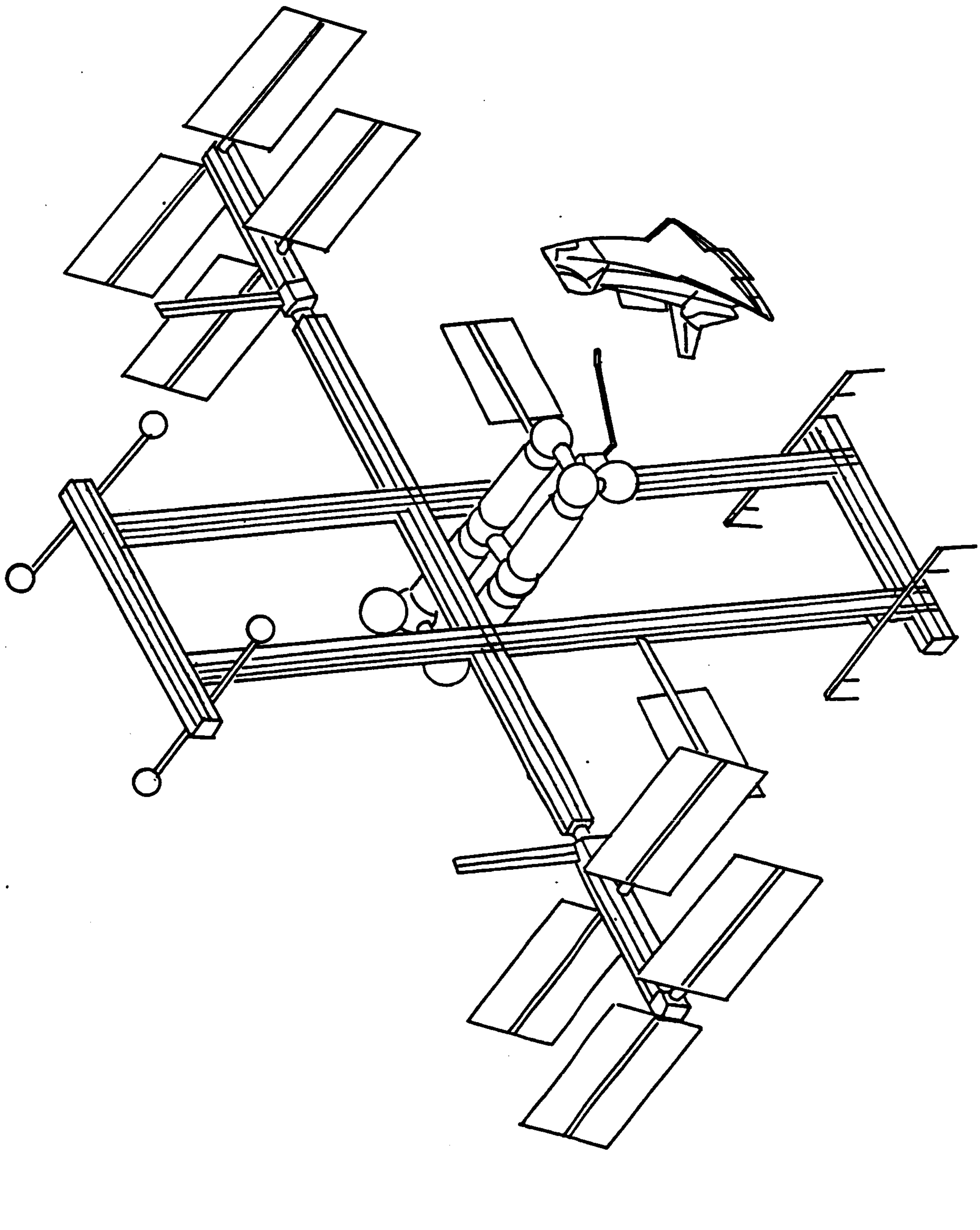

Figure 1. Space Station Configuration.

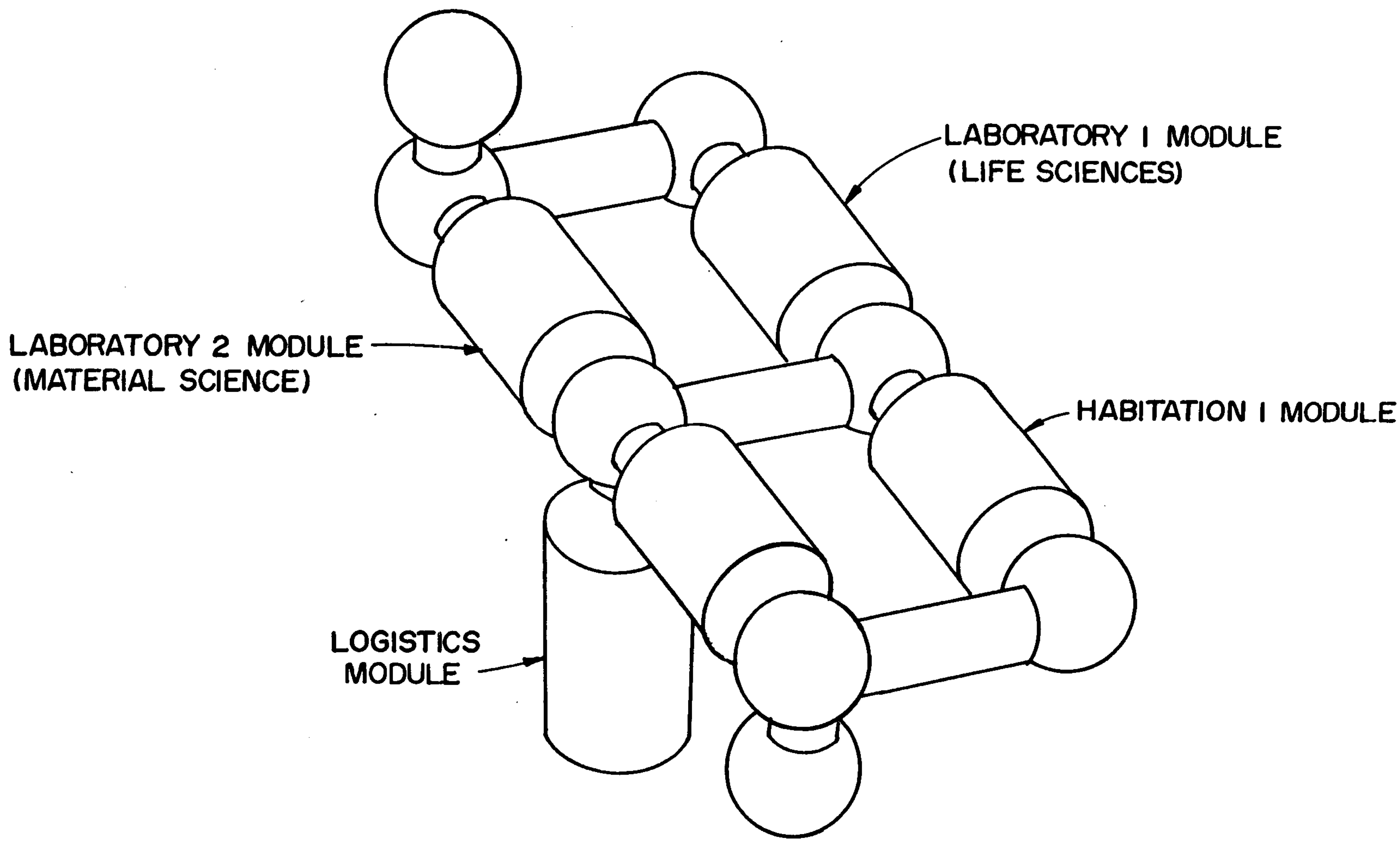

Figure 2. Station Modules.

Several candidate technologies are being considered for acquiring the waste heat loads, for transporting the thermal energy between the acquisition and rejection systems, and for rejecting the waste heat to space. The analysis techniques described here were developed for use in evaluating reliability, weights, costs, volumes, and power requirements for configurations using different candidates and different mission parameters.

EVALUATION TECHNIQUES

The thermal control system analysis program permits the user to analyze a space station thermal control system. The space station is assumed to be composed of seven distinct modules, each of which may have its own metabolic heat loads and equipment heat loads. In each of the modules, the user may specify the total metabolic load and the size and locations of the equipment loads. The metabolic loads are assumed to be acquired by air-water heat exchangers, transported by pumped liquid water loops, and rejected to space by body-mounted radiators attached to each of the modules which have metabolic loads. Because the metabolic loop is local to a module it is called an autonomous loop.

Heat loads generated by equipment in each module are assumed to be acquired by cold plates. The user may choose among the following candidates technologies for the cold plates in each module:

1. Conductive cold plate
2. Two-phase cold plate
3. Capillary cold plate

In addition, the user may locate up to five cold plates (each having a different capacity) in a module, choose the cold plate operating temperature, and specify the working fluid (water, ammonia or Freon-11). The user also has the option to specify whether the equipment loop is to be integrated or autonomous. If the equipment loop is integrated, the heat from the equipment is transported from the cold plates to the main heat transport system for eventual rejection to space by the main rejection system. On the other hand, if the equipment loop is autonomous, the heat from the equipment is rejected to space by body-mounted radiators located on the module exterior. In this case the user may specify separate candidate technologies for heat transport and heat rejection in the autonomous equipment loop.

The user may select from the following candidate technologies for the main heat transport system or the heat transport system for a module having an autonomous equipment loop:

1. Pumped liquid loop
2. Pumped two-phase loop
3. High capacity heat pipe

In addition, the user may choose the transport lengths and specify the working fluid.

For the main heat rejection system or the heat rejection system for a module having an autonomous equipment loop, the user may select from the following candidate technologies:

1. Heat pipe radiator
2. High capacity heat pipe radiator
3. Liquid droplet radiator

In addition, the user may choose the radiator surface temperature and the emissivity of the radiator surface.

WORK COMPLETED SINCE LAST REPORT

During the period covered by this report, efforts have been focused on the following tasks:

a. Increasing the user-friendliness of the Thermal Control System analysis program.

b. Responding to queries and suggestions for modifications to TCS program.

c. Comparing the TCS program assessment results with available data.

d. Developing and refining mathematical models in the TCS program.

Many new features have been added to the TCS program to increase its user-friendliness. The flow of the program has been modified substantially so that the user can better follow the operation and execution of the program. The organization of the sub-menus, as well as the responses requested from the user, have been standardized. In addition, upon having a sub-menu the user now consistently returns to the next higher level of menu.

Several apparent inconsistencies have been identified by personnel at NASA Langley during the past several months. In some instances, these have led to modifications to the source program. In other cases, more detailed explanations of the operation of the program have been sufficient. One of the modifications recently completed provides a summary of results from the line-sizing routines in a local file created during program execution. Included in this summary are mass flow rates, line sizes, pressure drops, wet and dry line weights, line volumes, heat exchanger data and power requirements. This information is now available for the equipment and metabolic loops on each module and for the main transport loop.

With the summary line-sizing information, the user can more readily compare the TCS program results with other available data. Such comparisons have been made with data from Rockwell and JSC reports and have been provided to Jack Hall at NASA/Langley under separate cover. The development of two new mathematical models has also been completed during the period of this report. One deals with the sizing and analysis of bus heat exchangers and the other provides a means of analyzing a variety of heat pipe radiator designs. The FORTRAN subroutine for the bus heat is nearly complete and will provide analysis data (i.e. weights, volumes, etc.) for single phase-single phase, single phase-two phase, or two-phase-two-phase bus heat exchanger in the metabolic loops, module equipment loops, and the main transport loop. Any combination of available fluids can be treated, and the user may also select the material from which the heat exchanger is to be constructed.

A generic heat pipe model has been added to the Thermal Control System Analysis Program. This model allows the user to incorporate any type of high capacity heat pipe radiator panel. The user must, however, know heat rejection capability, required surface area, weight and volume for a panel for one set of operating conditions. Operating conditions are condenser length, evaporator length, working fluid, absorptivity, emissivity and radiator temperature. The user may then select other values for working fluid, radiator capacity, temperature, emissivity and absorptivity. The analysis program then computes new areas, weights and volumes for the radiator. The steps are outlined as follows.

User Specifies:

Heat Rejected per panel Q_p (Kw)

Surface Area (both sides for double sided) A_p (ft^2)

Weight per panel m_p (lbm)

Volume per panel V_p (ft^3)

Cost per panel C_p ($)

For These Conditions:

Condenser length (ft)

Evaporator length (ft)

Absorptivity α_I

Emissivity ϵ_I

Radiator Temperature T_I (^oF)

Working Fluid Ammonia, R-11, Methanol or Acetone

User May Then Select:

Radiator Capacity Q_{II} (Kw)

Radiator Temperature T_{II} (^oF)

Emissivity ϵ_{II}

Absorptivity α_{II}

Working Fluid Ammonia, R-11, Methanol or Acetone

Program then computes surface area

$$A_{II} = A_P \frac{Q_{II}}{Q_P} \frac{\epsilon_I}{\epsilon_{II}} \frac{F\alpha_{II}}{F\alpha_{II}} \left(\frac{T_I + 460}{T_{II} + 460} \right)^4 \frac{N_I}{N_{II}}$$

where

$$F\alpha_I = 1 + 0.5 (\alpha_I - 0.2)$$

$$F\alpha_{II} = 1 + 0.5 (\alpha_{II} - 0.2)$$

N_I = fluid parameter for fluid listed in conditions

N_{II} = fluid parameter for fluid selected

Number of panels for

$$NP_{II} = A_{II}/A_P$$

Weight of radiator

$$m_{II} = NP_{II}\, m_p$$

Volume of radiator

$$V_{II} = NP_{II}\, V_P$$

A detailed description and explanation of the work summarized in this report will be included in the final project report.